LLRF Plans for SMTF

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Thanks to DESY, PISA, KEK, Fermilab, SLAC Colleagues

Outline

- Near-term (< 1.5 years) SMTF LLRF plan
- Long-term (> 1.5 years) SMTF LLRF plan and proposal

Near-term SMTF LLRF Needs

- Upgrade of A0 photo-injector (H. Edwards et al)
  - Capture Cavity 2 (CC2) Test at Meson Area
    - Scheduled for October 2005
    - 1.3 GHz 9-cell TESLA single cavity, no beam
  - Third Harmonics Cavity Test at Meson Area
    - Scheduled for early 2006
    - 3.9 GHz 13-cell single cavity, no beam

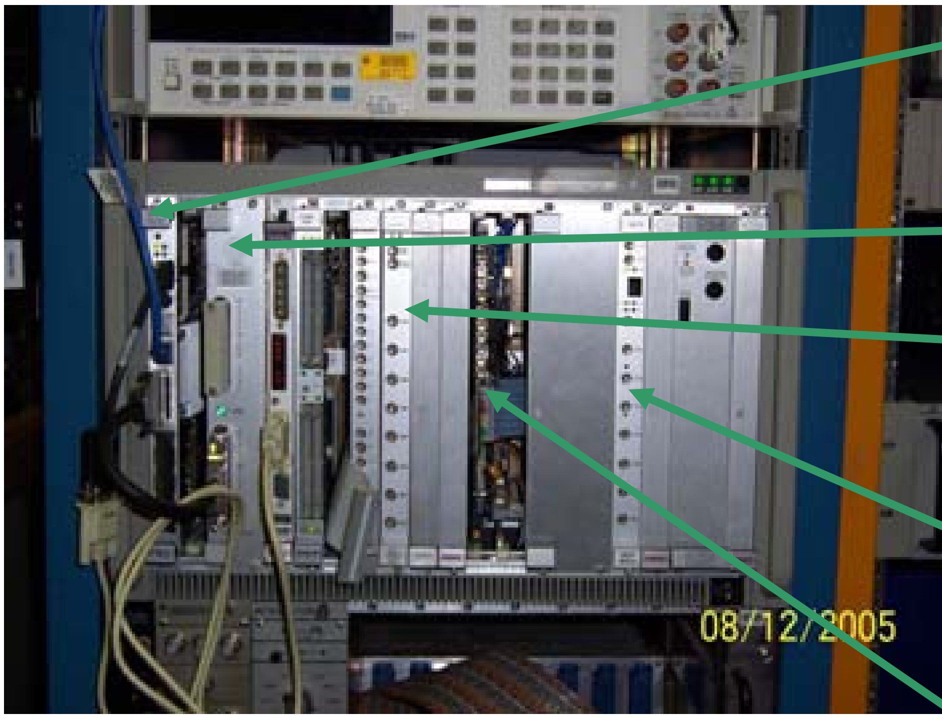
- ILC Cryomodule Test at Meson Area
  - Scheduled for late 2006
  - Eight 1.3 GHz 9-cell TESLA cavities fed from a single Klystron, no beam
- Horizontal Cavity Test Facility ("CHECHIA" style)
  - Scheduled for late 2006
  - 1.3 GHz or 3.9 GHz single "dressed" cavities, no beam

Near-term SMTF LLRF Plan

- Capture Cavity 2 Test
  - Use DESY Simcon 2.1 FPGA-based system (single cavity system)
  - A similar system has been used at the CHECHIA facility
- Third Harmonics Cavity Test
  - Modify the DESY Simcon 2.1 system for 3.9 GHz operation
  - If ready, use the 10-channel Simcon 3.1 system instead (multiple cavity system)
  - Consider other alternatives (e.g., the SNS LLRF system)
- ILC Cryomodule Test and Horizontal Cavity Test Facility
  - Use the DESY Simcon 3.1 system
  - Consider other alternatives, e.g.:
    - The SNS LLRF system, modified to include vector sum control
    - A LLRF system based mostly on commercially available hardware

First SMTF LLRF Crate (Simcon 2.1)

Simcon 2.1 was already used at Fermilab to run the A0 Capture Cavity 1 in March 05 and again in May 05



Other Modules not shown: Master Oscillator, Timing board, Vector Modulator, Mixer, and fast RF switch

VME Modules:

-Sparc CPU-56 running DOOCS and Matlab

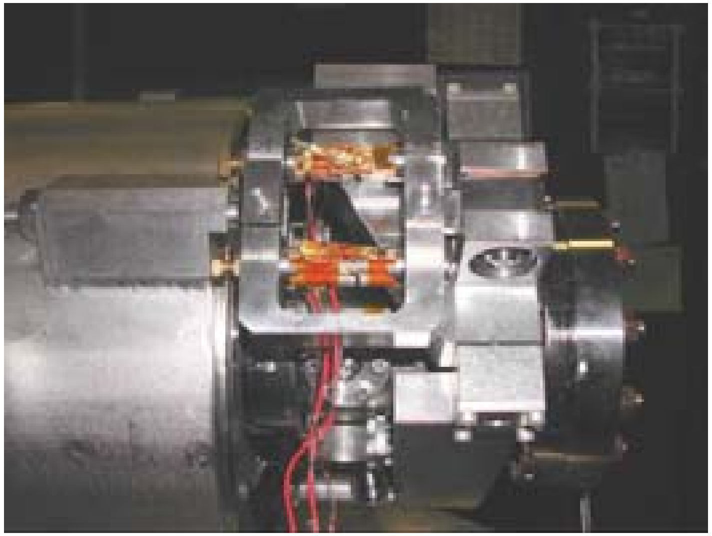
-Hard Disk

-8-Ch, 10 MHz fast digitizer (DESY design)

-8-Ch Function Generator board (DESY design)

-Simcon 2.1 FPGA board (DESY design + commercial FPGA board)

First SMTF Fast Tuner (piezo)



The current dual-piezo DESY bracket design does not perform well due to preload loss after cooldown and interaction with stepping motor action to bring the cavity to 1.3 GHz

The plan for CC2 test at SMTF is to go back to the simpler single-piezo DESY design, perform mechanical modeling, and add diagnostics instrumentation (strain gauges, capacitance measurements) to understand preload changes

First SMTF Magnetostrictive Fast Tuner

This tuner plus associated electronics has been ordered from Energen, Inc. and is designed to be a direct replacement of the DESY piezo bracket

Fast Tuner Specifications

Actuator:

Stroke[1]: 15 μm against a 1500 N load with a stiffness of 3 N/μm

Resolution: better than 4 nm

Slew rate: 0 to full stroke in 960 μs

Physical Dimensions: 50mm x 22mm x 62mm

Operating Temp: < 18 K

Force: 1500 N

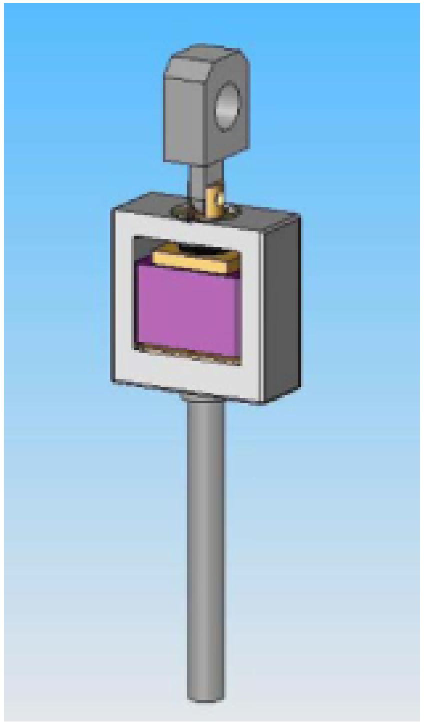
Bandwidth: 250 Hz

Heat Load to 2.1 K: ~ 0.1W

Operating Pressure: 1×10^{-6} Torr to 1 atm

Lifetime: > 10^{8} cycles

Inductance: ~ 12mH



Work at Penn (2 efforts)

- Written cavity simulator based on thesis of Thomas Schilcher (“Vector Sum Control of Pulsed Accelerating Fields in Lorentz Force Detuned SC Cavities”)
- Simulated as a lumped LCR circuit-solve DE equations
- Added cavity detuning, Q-drop, and RF Phase Jitter
- Use to test algorithms and understanding

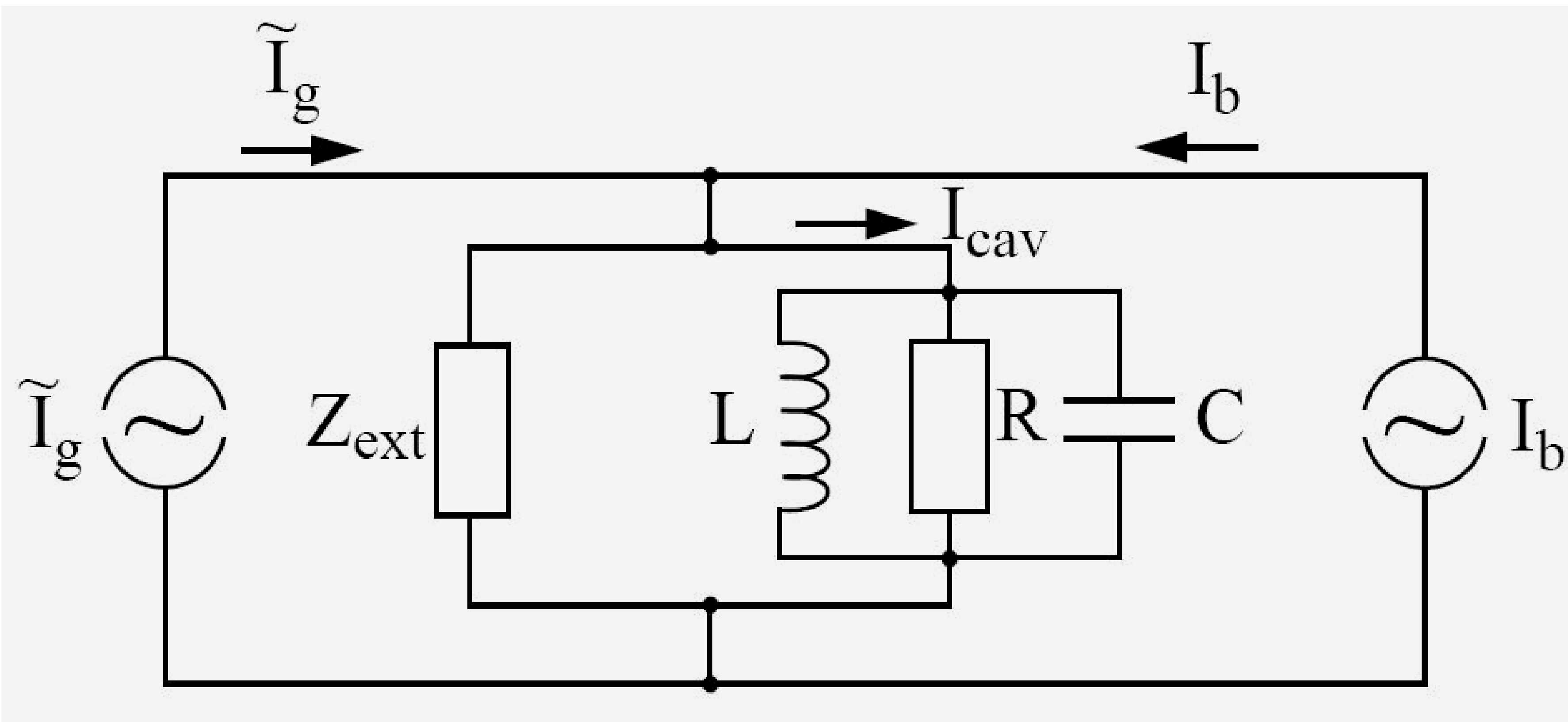
- Implementing digital architecture using industrially produced modules
- Follow lead of bus choice from KEK/JPARC “cPCI”
- establish limitations empirically
- Algorithms will be big effort

Super Conducting Cavity Simulation Model

-cavity simulation model is based upon T.Schilcher's PhD thesis http://tesla.desy.de/~simrock/llrf/schilcher.pdf

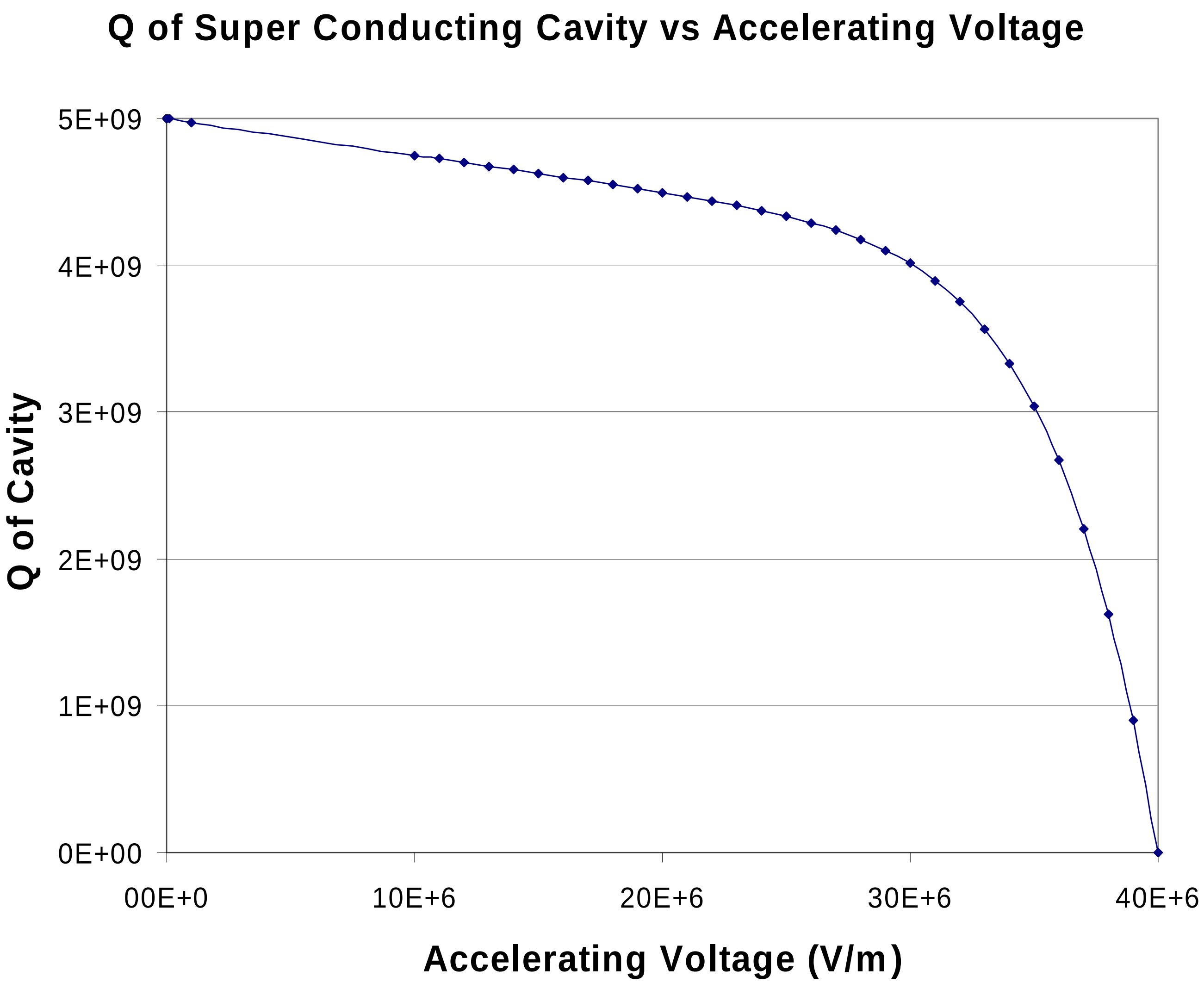
-treat the RF cavity as a lumped LRC circuit, and model the cavity properties by their effects on the how the oscillator resonates

-includes: Lorentz Force Detuning, Cavity Q-drop, phase jitter



Cavity Q drop Simulation Model

- the cavity decreases in Q as the accelerating voltage is increased

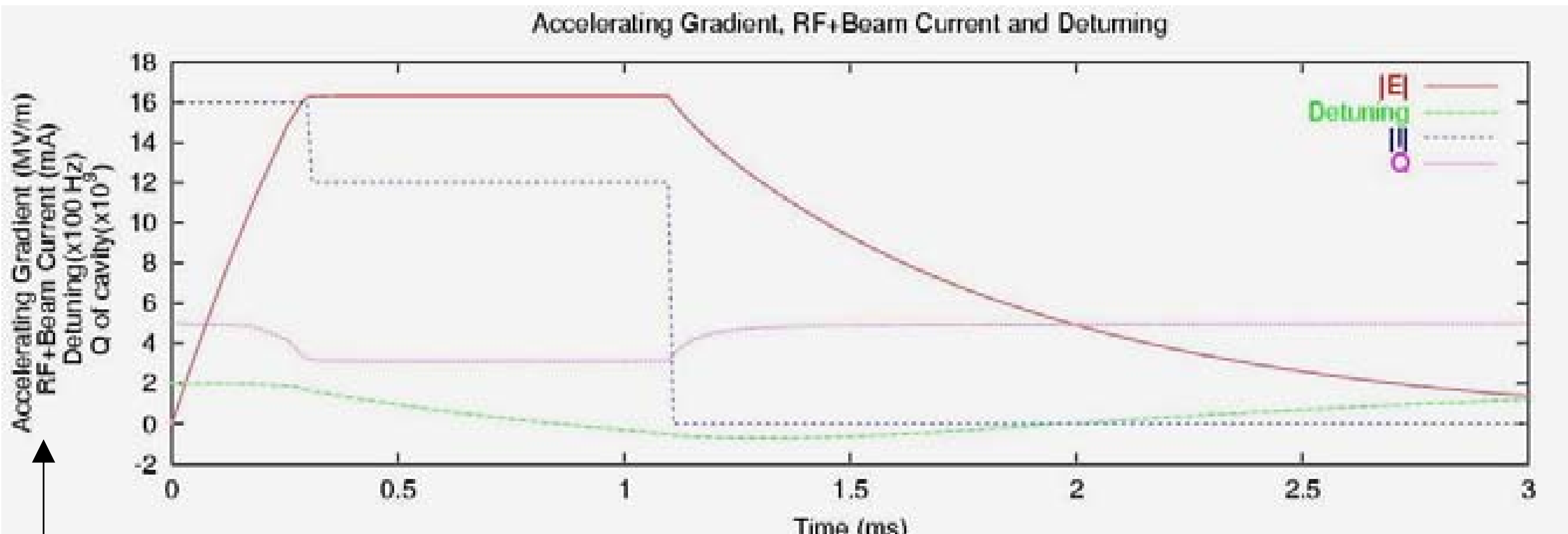


Prelim-Results: Cavity Fill-Hold-Empty

-RF power is supplied to the cavity to increase the field, then reduced to hold the field steady, then stopped to empty the field

-The period of flat top is used to accelerate the beam

-Since cavity detunes, we compensate that by pre-counter-detuning it

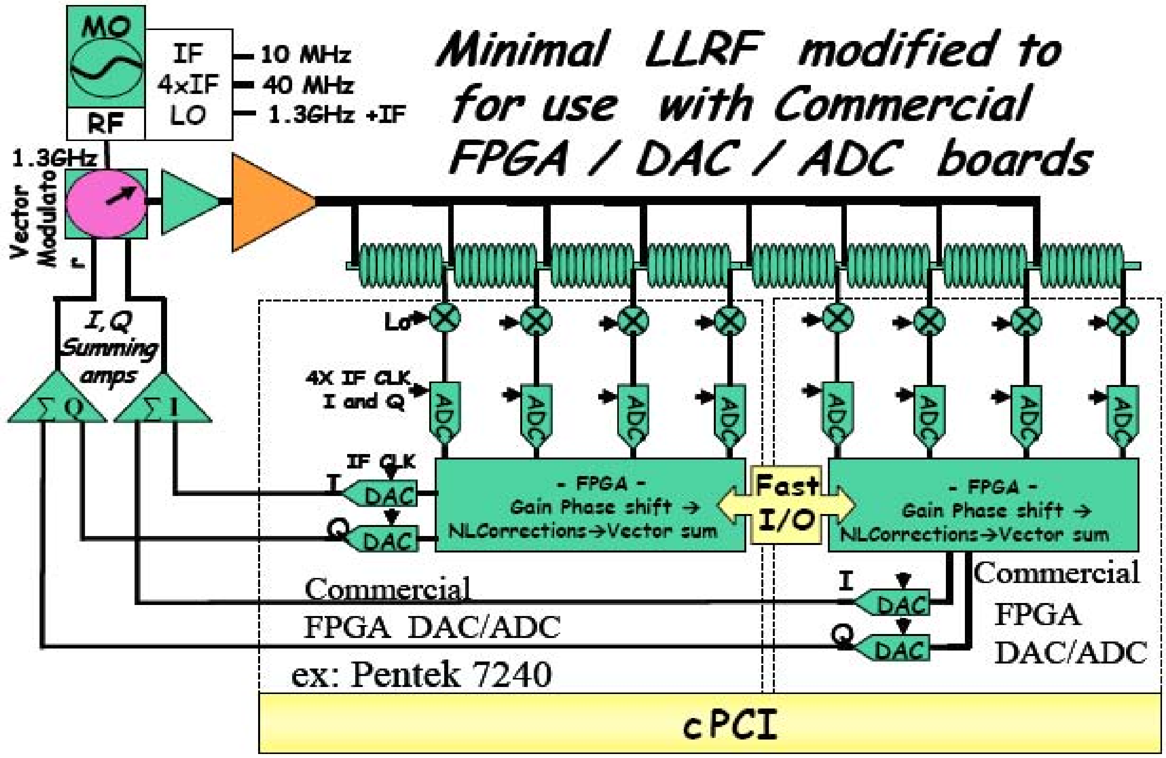


Note the different scales. Caveat: cavity parameters are not accurate, thus values do not accurately reflect reality. The shapes are however a good indication of what to expect.

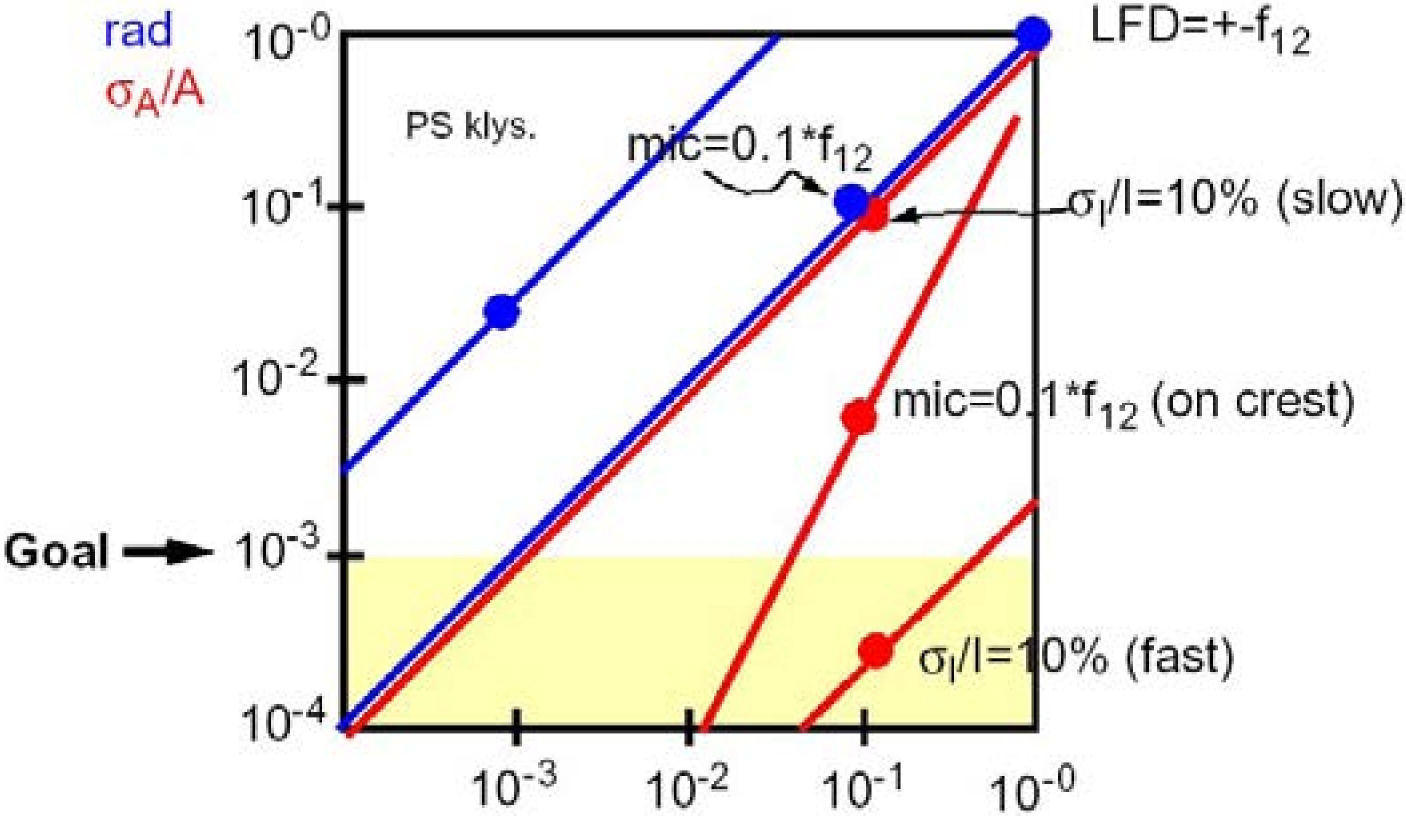
| E | = Accelerating Gradient

| I | = RF + Beam Current. (For this simulation Beam Current = 0)

Proposed Block Diagram of LLRF for SMTF(all commercial)



XFEL & ILC LLRF Specifications similar



R&D Issues

- Present DESY system established for a small number of cryomodules at low gradient
- Need to develop system at high gradient-much tougher
- Evaluate multiple systems idea (bunch compressor, linac..)
- Control of phase over full length of machine-difficult
- Deal with single point failures (eg. Master Oscillator)
- Establish needed gain of system (location of electronics, klystrons)
- Beam based feedbacks (not done presently) at TTF
- High degree of automation

Future Plans (Developing)

- ILC needs a LLRF specifications document
- Specifications for LLRF for ILC similar to that of X-FEL
- Factor of 3 increase in phase jitter specification in last week for ILC (thanks to PT) (we have a long way to go)
- Continue to develop industrial solutions (issues for access to schematics, firmware etc)

- Propose all three regions work together on X-FEL/ILC LLRF specification documents
- Prototype hardware may differ in three regions
- Aim to use same software architecture & strategy
- GDE supports/funds ILC portion for test facilities (STF&SMTF)

Summary

- The DESY LLRF System Simcon 2.1 (single cavity) and Simcon 3.1 (multiple cavities) has been the first choice to provide SMTF LLRF capabilities.
- Fermilab is working towards providing a complete stand-alone Simcon 2.1 LLRF system for the first SMTF single-cavity tests (1.3 GHz and 3.9 GHz)
- Plan on developing a specifications documents with all three regions and X-FEL
- Possible close collaboration/involvement with DESY on X-FEL by all three regions

Useful LLRF URL

http://rutherford.hep.upenn.edu/~lockyer/llrf.html